LXXXVIII. *A Letter of Mr.* James Short, *F. R. S. to the* Royal Society, *concerning the Inventor of the Contrivance in the Pendulum of a Clock, to prevent the Irregularities of its Motion by Heat and Cold.*

Gentlemen,

Read Nov. 9, 1752.

THE ſubject of converſation of late having often turn'd upon that ingenious contrivance in the pendulum of a clock, to prevent the inequalities in its motion, ariſing from its different lengths, in different ſeaſons of the year, by the effects of heat and cold; and it having been often aſked, who was the inventor of it, I have therefore thought proper to draw up the following hiſtorical account of it: And as this account contains nothing but matters of fact, ſupported by the beſt authorities, I hope it will be acceptable to this Society. I am

Your moſt obedient humble ſervant,

J. Short.

SOON after the invention of pendulum-clocks (juſtly aſcribed to the celebrated Mr. Huygens), it was found, that they were liable to conſiderable inequalities in their motion; which were imagined to ariſe from the pendulum, in its vibrations, deſcribing an arc of a circle; and, conſequently, that the larger vibrations muſt be ſlower than the ſhorter ones.

ones. In order to remedy this imperfection, the ſame Mr. Huygens wrote a treatiſe, called *Horologium oſcillatorium* (a piece of geometry, which does honour to the laſt century), in which he demonſtrates, from the properties of the cycloid, that the vibrations of a pendulum, moving in a cycloid, would be perform'd in equal times, even tho' the vibrations were unequal. Pendulums therefore were made to vibrate in a cycloid; but great inequalities were ſtill obſerv'd in the motion of clocks.

We do not read of any attempts, after this, to regulate the motion of clocks, till the year 1726, when Mr. George Graham deliver'd into the Royal Society a paper, which is publiſh'd in the *Phil. Tranſ.* Nº 392, in which he ſays, that it having been apprehended, that the inequalities in the motion of clocks aroſe from a change of length in the pendulum, by the influences of heat and cold, he, about the year 1715, made ſeveral trials, in order to diſcover, whether there was any conſiderable difference of expanſion between braſs, ſteel, iron, ſilver, *&c.* when expoſed to the ſame degrees of heat; conceiving, that it would not be very difficult, by making uſe of two ſorts of metals differing conſiderably in their degrees of expanſion and contraction, to remedy, in great meaſure, the irregularities, to which common pendulums are ſubject. He ſays alſo, that, from the experiments he then made, he found their differences ſo ſmall, as gave him no hopes of ſucceeding that way, which made him leave off proſecuting this affair any more at that time: That, ſome time after, having obſerved an extraordinary degree of expanſion, by heat, in quickſilver, he thought of a proper manner

manner of applying a column of it to the pendulum of a clock, in order to prevent the inequalities ariſing from its different lengths by the effects of heat and cold; which ſucceeded accordingly, and is what is now called Mr. Graham's quickſilver-pendulum.

Mr. Graham, in the ſame paper, takes notice, that, tho' the pendulum of a clock was to remain invariable, yet there would ſtill be ſome irregularities in the motion of the clock, ariſing from the friction of the different parts of the clockwork, and from the different degrees of foulneſs.

In the year 1725, Mr. John Harriſon, of Barrow in Lincolnſhire, made ſeveral experiments upon wires of different metals, in order to find their different degrees of expanſion and contraction: For he thought, that, by a proper combination of wires of two different metals, differing conſiderably in their expanſion and contraction, he might be enabled to keep the centre of oſcillation of a pendulum always at the ſame diſtance from the point of ſuſpenſion. In conſequence of theſe experiments, he made a pendulum, conſiſting of one ſteel wire, at the end of which is the bob or weight, and, on each ſide of this wire, four wires alternately braſs and ſteel, ſo diſpoſed and contrived, as to raiſe the pendulum the ſame quantity as it is lengthen'd by heat, and to let down the pendulum in the ſame proportion as it is raiſed by cold. He made alſo a drawing of a clock, in which the wheels are diſpoſed in a different manner from thoſe then in uſe; which drawing I have ſeen, ſigned by himſelf in the year 1725. Two of theſe clocks with pendulums, as deſcribed above, were finiſhed in the year 1726. In theſe clocks Mr. Harriſon has made a particular a particular ſort of pallets, ſo as to be almoſt intirely free from friction; for tho' he had thus happily ſucceeded in his contrivance to prevent the inequalities in the motion of the clock, ariſing from the different lengths of the pendulum by the effects of heat and cold, yet he found there were conſiderable errors ſtill remaining, occaſion'd by the friction of the pallets, as in the common way. He has alſo ſuſpended the pendulum upon the wall of the houſe, intirely independent of the clock and clock-caſe: For he had obſerved conſiderable alterations in the going of the clock, when the pendulum is ſuſpended as in the common manner. His pendulum vibrates in an arc of about 15 degrees, with a bob of about three pounds, between cycloidal checks, which he himſelf found were neceſſary, tho' he had never heard of M. Huygens's book, till after he had made them. He has alſo diſpoſed the force of his pendulum-wheel upon the pendulum, by his ſort of pallets, in ſuch a manner, that the vibrations of the pendulum will not be affected by the different reſiſtance of the air. Upon the whole, this clock is made in ſuch a manner, as to be almoſt intirely free from friction; in conſequence of which he uſes no oil, and therefore there is no neceſſity ever to clean the clock. When he ſettled in London, he ſent for one of theſe clocks from the country, and ſet it up in his houſe in Orange-ſtreet, in the year 1739, where it has ſtood ever ſince, and in all that time has never varied above one minute from the truth. He can depend upon it to a ſecond in a month.

About the year 1729, Mr. Harriſon made his firſt machine for meaſuring time at ſea, in which he has likewiſe

likewiſe applied this combination of wires of braſs and ſteel, to prevent any alterations by heat and cold. In the year 1726, he went on board one of His Majeſty's ſhips of war with this machine to Lisbon, and returned, where this machine was ſeen by every curious and ingenious perſon, who were pleaſed to go to his houſe. Since that time, he has made two more of theſe machines or clocks for keeping time at ſea, in both which he has likewiſe this proviſion, to prevent the effects of heat and cold.

An account of theſe curious machines, and of the many ingenious contrivances which Mr. Harriſon has made uſe of in them, for anſwering their intended purpoſe, and alſo an account of the ſucceſs of his voyage to Lisbon, and back again, is contained in an excellent ſpeech of our worthy Preſident Martin Folkes, Eſq; upon his delivering to Mr. Harriſon the gold medal of Sir Godfrey Copley; which ſpeech is inſerted in the minutes of the Society in the year 1749.

Mr. John Shelton, who was the principal perſon employed by Mr. Graham in the making of aſtronomical clocks, informs me, that Mr. Graham, in the year 1737, made a pendulum conſiſting of three bars, *viz.* one of ſteel, between two of braſs, and that the ſteel bar acted upon a lever, ſo as to raiſe the pendulum, when lengthened by heat, and to let it down, when ſhortened by cold. This lever, which is very ſtrong, reſts upon a roller; which roller is made moveable, ſo as to adjuſt the arms of the lever to their true proportion. The whole was made to be as free from friction, as poſſible, in ſuch a conſtruction. Mr. Graham made obſervations, by tranſits of the fixed ſtars, of the motion of the clock with this ſort of pendulum, and from the experience of ſeveral years (during which the clock was kept conſtantly going) he found, that the clock was liable to ſudden ſtarts and jerks in its motion. Of this he informed Dr. Bradley, Mr. Bliſs, myſelf, and ſeveral other gentlemen. This clock ſtill remains in Mr. Graham's houſe, in the poſſeſſion of his executors.

I have been informed, that one Mr. Frotheringham, a quaker, of Lincolnſhire, cauſed a pendulum to be made, conſiſting of two bars, one of braſs, and the other of ſteel, faſten'd together by ſcrews, with levers to raiſe or let down the bob; and that theſe levers were placed above the bob. This clock I have ſeen, and was told by the maker, Mr. John Berridge, that the pendulum of it was made in the year 1738, or 1739, and that the dial-plate of it was engraved at Mr. Siſſon's houſe in the year 1738: and this clock is in the poſſeſſion of Mrs. Gibſon, in Newgate-ſtreet, who has had it ever ſince the year 1739.

In the *Hiſt. of the Royal Acad. of Sciences at Paris*, for the year 1741, there is a memoire of M. Caſſini, in which he deſcribes ſeveral ſorts of pendulums for clocks, compounded of bars of braſs and ſteel, and applies a lever to raiſe or let down the bob of the pendulum, by the expanſion or contraction of the bar of braſs. He has alſo given us, in the ſame memoire, a problem for finding the proportion, which the two arms of the lever ſhould have, to anſwer the intended purpoſe; and alſo a demonſtration of it.

In June, 1752, Mr. John Ellicott gave in to the Royal Society a paper, containing the deſcription of a pendulum, conſiſting of two bars, one of braſs, and the other of iron, faſtened together by ſcrews, with two levers in the bob of the pendulum, ſo contrived, as to raiſe and let down the bob, by the expanſion and contraction of the braſs bar; and alſo to adjuſt the arms of the levers to their true proportion *. He ſays, that he firſt thought of theſe methods of applying bars of braſs and iron to prevent the irregularities of a clock, ariſing from the different lengths of the pendulum, by the effects of heat and cold, in the year 1732; and that he put this his thought in execution in the year 1738.

In the year 1743, I bought a clock of Mr. Graham, which he had kept going for two years before. This clock has a pendulum, compounded of wires of braſs and ſteel, in the manner of Mr. Harriſon's combination. It has alſo a proviſion in the bob, to adjuſt the wires, in caſe they happen to be too long. When I firſt took notice of this contrivance or proviſion in the bob, I aſked Mr. Graham the reaſon of it; who told me, that, having obſerved ſome inequalities in the motion of the clock, he imagined, that they aroſe from the wires being ſomewhat too long; and there-

fore

---

* He has alſo given us in the ſame paper another conſtruction of a pendulum to prevent the effects of heat and cold, conſiſting of two bars, one of braſs, and the other of iron; the braſs bar acting upon a lever, at the end of which is faſtened the pendulum, the whole ſo conſtructed and contrived, as to raiſe the pendulum, when it is lengthened by heat, and to let it down, when ſhortened by cold.

fore added this contrivance, to adjuſt the length of the wires; but that, when he had done this, he found inequalities ſtill remaining; and therefore juſtly concluded, that they aroſe from the difference in the friction of the different parts of the clockwork, occaſioned by the differences in the fluidity of the oil, *&c.*

From what has been ſaid above, it appears, that the improvement of clocks, by a contrivance to prevent their inequalities ariſing from the different lengths of the pendulum, in different ſeaſons of the year, by the effects of heat and cold, was firſt thought of, and executed, by Mr. George Graham; and that the application of wires or bars of two metals, which have different degrees of expanſion or contraction, to prevent the ſame inequalities, was alſo firſt thought of by Mr. Graham, and firſt executed by Mr. John Harriſon, without the leaſt knowlege of what Mr. Graham had done before him.

LXXXIX. *A Letter from Mr.* Henry Eeles, *to the* Royal Society, *concerning the Cauſe of* Thunder.

Gentlemen,

Liſmore, Ireland, June 18, 1752.

Read Nov. 7, 1752.

THE greateſt men of moſt ages having thought it worth the while to inquire, what was the cauſe of thunder; and the world ſeeming to acquieſce in an hypotheſis ſubſcrib'd by ſome great modern names, it muſt appear preſumptuous in me, to offer you ſome thoughts for a theory intirely new (at leaſt it is ſo to me) unleſs I can ſhew, that the former hypotheſes are ill-grounded,